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Sideroblastic Anemias: Variations on Imprecision in Diagnostic Criteria, Proposal for an Extended Classification of Sideroblastic Anemias

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Sideroblastic anemias are caused by a diversity of hereditary, congenital, or acquired disorders. Criteria used in describing sideroblastic anemias vary widely among standard medical textbooks and even so have been imprecisely applied in the literature. Recent discoveries concerning the basic pathophysiologic mechanisms involving the molecular biology of nuclear and mitochondrial DNA, erythroid ALA synthase (ALAS-2), and iron transport have made the classification of sideroblastic anemias very complex. We recommend a more precise evaluation and documentation of the components that characterize the sideroblastic abnormality and propose an extended classification of the sideroblastic anemias. Am. J. Hematol. 57:1–6, 1998. © 1998 Wiley-Liss, Inc.

Key words: sideroblastic erythropoiesis; mitochondrial and nuclear DNA disorders

The demonstration of iron-overloaded mitochondria within nucleated red cell precursors by electron microscopy or energy-dispersive X-ray analysis [1] establishes the morphologic diagnosis of sideroblastic erythropoiesis. The universally accepted, more practical surrogate for this technique is the demonstration by Perls' Prussian-blue iron stain of increased numbers of siderotic granules that are abnormal in size and distribution around the nuclei of developing red cells in bone marrow aspirates. These are, of course, the abnormal ring (or ringed) sideroblasts, which, when present in greater than 10% of the red cell precursors, form the cachet and basic diagnostic criterion of sideroblastic erythropoiesis and the sideroblastic anemias. These abnormal ring sideroblasts contain within their mitochondria non-ferritin, ''ferruginous,'' iron complexes. They are clearly separable from the sideroblasts that occur in 20 to 60% of the normal erythroid maturation series and in which the siderotic granules are composed of ferritin/hemosiderin clusters and the mitochondria contain no visible iron. Until specific, etiologic mechanisms are established for the greatly diverse subclasses of sideroblastic anemias, this morphologic manifestation remains the current hallmark upon which to base a diagnosis. Unfortunately, a review of the literature reveals that qualitative and quantitative evaluations and descriptions of sideroblastic changes have been very loosely and non-uniformly proposed and applied.

This will be illustrated by quotes from standard hematology and internal medicine texts and from a survey of ''sideroblastic literature,'' which document the diversity of criteria in use and demonstrate the need for more uniform reporting. We shall then propose a formula such that, with more uniform reporting, subclasses may be better separated for accurate comparative studies and for possible indicators of etiologies, prognoses, and responses to therapy. These changes have been provoked by and are urgently needed because of the recent major advances made concerning the sideroblastic anemias in relation to basic mechanisms involving the enzymology of vitamin B_6 and of heme production, and especially the molecular biology of nuclear and mitochondrial DNA, erythroid ALA synthase (ALAS-2), and iron transport. Table I lists the suggested criteria for making the diagnosis of sideroblastic anemia found in standard hematol-

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TABLE I. Recommended Criteria for Diagnosis of Sideroblastic Anemia Provided in Standard Texts

Author/source	Size of siderotic granules	Number of siderotic granules	Distribution of siderotic granules	Extent of granules around nucleus	Proportion of abnormal sideroblasts			Predominant occurrence	
					Erythroid series	Total nucleated cells	Unspecified	Late erythroid normoblasts (hereditary)	Early and late erythroid stages (acquired)
Nelson [2]	"Coarse granules"		"Perinuclear collar"						
Bennett et al. [3] (FAB)						>15%			
Cecil [4]		Greater than normal	"Perinuclear distribution"	"Surrounding the nucleus"					
Williams [5]			"Circumnuclear arc"	"Ring"			>15%	+	+
Dacie and Lewis [6]			"Arranged in a collar around the nucleus"		>15%			"More mature cells seem more affected"	"All stages of maturation"
Greenberg et al. [7] (FAB)					>15%				
Handin et al. [8]	"Large"	>5		"More than one-third"					
Hardisty and Weatherall [9]	"Large, coarser"	"More numerous"	"Clustered around nucleus in the form of ring or collar"		"Majority"				50–100%
Hoffbrand and Pettit [10]				"Complete or nearly complete rings"			>15%		20–50%
Hoffman et al. [11]				"One-third or more"	>15%				
Harrison [12]				"Surround"	>10%				
Jandl [13]	"Abnormally large"	>5–6	"Perinuclear arc"	"One-third or more"	>10%			10–40%	40–90%
Wintrobe [14]	"Abnormal"	>5		"Partial or complete"	15–100%			+	+
Miller et al. [15]			"Perinuclear necklace-like"		"Large, number"			+	+
Nathan and Oski [16]				"Halo surrounding the nucleus"				+	+
Tierney et al. [17]			"Encircling red-cell nucleus"						
Weatherall et al. [18]			"Perinuclear region"	"Ring or heavy collar"	>15%				

TABLE II. Descriptions of Sideroblastic Anemias Quoted in the Literature

Qualitative descriptions	Not further characterized	Quantitation provided relative to erythroid series	Quantitation provided but not further specified
"Rare ring sideroblasts" "rare ringed forms"	"Abnormalities compatible with sideroblastic anemia"	"Ring sideroblasts occupied 37% of erythroblasts"	"1% ringed forms"
"Occasional ring sideroblast"	"Siderocytic"	"50% n.r. had many iron granules, 1/2 with typical perinuclear arrangement"	"2–5% ring sideroblasts"
"Some ring sideroblasts"	"Sideroblasts were present"	"98% of normoblasts were sideroblasts and 26% were ringed"	"71% sideroblasts and 11% ringed sideroblasts"
"Few ring sideroblasts"	"Sideroblastic anemia"		"Around 10% ring sideroblasts"
"A number of ringed sideroblasts"	"Marked sideroblastic features"		"10% complete and 15% partial ringed forms"
"Abundant ringed sideroblasts"	"Pathological ringed sideroblasts," "PRS"		"50% ring forms"
"Appreciable number of ring sideroblasts"	"Sideroblastic rings"		"At least 60% ringed sideroblasts"
"Frequent ringed sideroblasts"	"Abundance of normoblasts with stainable iron inclusion (ring sideroblasts)"		
"Multiple ringed sideroblasts"	"Ringed sideroblasts were present"		
"Increased ringed sideroblasts"	"Ring form sideroblasts"		
"Numerous ringed . . . sideroblasts"	"Ringed sideroblasts were seen"		
"Many abnormal sideroblasts including numerous ringed sideroblasts"	"Dyserythropoiesis with ringed sideroblasts"		
"Most of later forms were ring sideroblasts"	"50% of nucleated cells were ringed sideroblasts"		
"Marked increase in the number of sideroblasts, many of them ringed forms"			
"Marked ringed sideroblasts"			
"Large amount of typical ringed sideroblasts"			
"Large number of ringed sideroblasts"			
"Many ringed sideroblasts"			
"High number of distinctive ringed sideroblasts"			
"Ring sideroblasts in great numbers"			
"Great numbers of ring sideroblasts"			

ogy (adult and pediatric), internal medicine, and pediatric texts.

A review of the ''sideroblastic literature'' and case reports reveals that for the most part there is disregard for quantitation but rather use of colorful qualitative descriptors. One report incorrectly uses the term ''siderocyte'' in referring to the abnormal nucleated erythroid precursor of an otherwise evident sideroblastic anemia. Seldom is the *size* of the siderotic granules stated as normal or abnormal and only occasionally is the number of granules indicated to be greater than the up-to-four found in normal sideroblasts. It is distinctly unusual to encounter a description of how far the granules extend in an arc or ring around the nucleus and whether they are ''tight around the nucleus,'' grouped in a cluster (''capped''), or at near random distribution throughout the cytoplasm.

Whether the increased numbers of abnormal siderotic granules exist mainly in normoblasts (hereditary) or show up in the early erythroid precursors with persistence into later stages (acquired, idiopathic, or secondary) is only occasionally documented. Because the major interest is in the altered erythropoiesis, and because of marked variability in these circumstances in the M:E ratio, it can be of importance to state whether the proportion of abnormal sideroblasts is quantitated in terms of erythroid precursors alone, as a proportion of erythroid plus neutrophilic series, or as a proportion of total nucleated cells. As illustrated in the following quotes, this is variably accounted for, but frequently no indication is provided to enable the reader to determine which proportion is indicated.

While viewing the following quotes in Table II (not attributed), it should be pointed out that in most of the reports the clinical situation, other laboratory findings, and response (or lack of response) to therapy clearly indicated an abnormal sideroblastic process. When, oc-

casionally, *electron microscopy* or energy dispersive X-ray analysis was presented, the diagnosis was established.

RECOMMENDATIONS FOR DIAGNOSIS OF SIDEROBLASTIC ANEMIAS

If studies employing electron microscopy or energy-dispersive X-ray analysis are not available, it is strongly recommended that the following components be evaluated and documented when erythropoiesis is assessed on the basis of Perls' Prussian-blue iron stains of bone marrow aspirates or peripheral blood. In this evaluation, it should be recalled that iron deficiency may decrease the expression of the abnormal as well as the normal sideroblasts.

1. Are the siderotic granules larger than those found in normal sideroblasts, which are usually just within the resolution of the 100× oil immersion lens?
2. Are the numbers of granules found in the cells greater than the up-to-four present in normal sideroblasts?
3. Are the granules distributed at random throughout the cytoplasm or do they have a preferential distribution, approximately ringing or arcing around the nucleus (as do the mitochondria or developing erythroid cells)?
4. How far do the siderotic granules extend in circling the nucleus or do they tend to group in clusters ''capping'' the nucleus?
5. What is the percent of abnormal ring sideroblasts present when expressed as the proportion of nucleated erythroid cells (preferable), as the proportion of erythroid plus neutrophilic series (when E:M ratio is also supplied), or as the proportion of total nucleated cells (when differential count is supplied)?
6. Do the siderotic granules occur mainly in the orthochromic and polychromic normoblasts (as described mainly for the hereditary forms of sideroblastic anemias), or do the iron granules occur in abnormal numbers and size beginning with the early basophilic erythroblast forms and extending to normoblast stages (as described mainly for the acquired idiopathic and secondary forms of the sideroblastic anemias)?
7. An evaluation of iron stores (on a 1 to 6 scale) by survey of at least three marrow particles may also be of interest although peripheral to the main objective of sideroblast evaluation, as are the determinations of MCV, RDW, RBC size distribution, and erythrocyte protoporphyrin.

Table III is made up of a listing of reported cases of sideroblastic anemias and is offered in the form of a proposed extended classification of sideroblastic anemias. To justify and document the existence and position for each of the headings or subgroups, one or more illustrative general reference or specific case report selected from the literature is provided in the References.

TABLE III. Sideroblastic Anemias*

Hereditary sideroblastic anemias [19, 20]
- **Nuclear DNA** [19, 20]
  - **X-linked** [21–23]
    - (X)(p11.21)(ALAS-2) (point mutations) [21] (*301300)
    - (X)(q13)(SA/A) linked to phosphoglycerate kinase [24] (311800)
    - Linked to G-6PD deficiency [25] (*301300)
    - SA/A [26] (301310)
  - **Autosomal** [27] (182170)
  - **Autosomal dominant** [28] (182170)
  - **Autosomal recessive** [19]
    - (X)(p11.21)(ALAS-2 excluded) [29]
    - Thiamine responsive megaloblastic anemia [30,31] (*249270)

Congenital, hereditary, or acquired sideroblastic anemias (OXPHOS diseases) [32–34]
- **Mitochondrial DNA** [33–35]
  - **CPEO** [33,34], **PS** [20, 36–39] (#557000)
  - **K-S** [39–42] (#530000)
  - **DIDMOAD** [43, 44], **RARS** [45] (point mutations, deletions, additions, duplications of mt DNA)
  - **RARS,** point mutation; mt $tRNA^{leu(CUN)}$[46]
- **Nuclear DNA driven mitochondrial dysfunction** (proposed) [47] (600462)

Acquired sideroblastic anemias [19]
- **Idiopathic (AISA)** [19]
  - **PSA,** dyserythropoiesis [48, 49]
  - **RARS,** myelodysplastic [48, 49]
- **Nuclear DNA**
  - **PSA,** dyserythropoietic (X)(p11.21)(ALAS-2) [50] (*301300,0005)
  - **RARS,** myelodysplastic
    - (X)(q13) [51]
    - Idic (X)(q13) [52, 53]
    - 11q- [54]
- **Secondary** [19, 55]
  - Systemic, metabolic, malignant disorders
- **Reversible** [19]
  - Alcohol, Cu deficiency, toxicity, hypothermia, drugs, Zn [18, 56–58]

*The numbers in the parentheses refer to the database (Online Mendelian Inheritance in Man: OMIM) which is a catalog of human genes and genetic disorders, authored and edited by Dr. Victor A. McKusick et al., and developed for the World Wide Web by NCBI (the National Center for Biotechnology Information).

REFERENCES

1. Trump BF, Berezesky IK, Jiji RM, Mergner WJ, Bulger RE: Energy dispersive X-Ray microanalysis of mitochondrial deposits in sideroblastic anemia. Lab Invest 39:375–380, 1978.
2. Behrman RE, Kliegman RM, Arvin AM: ''Nelson Textbook of Pediatrics,'' 15th ed. Philadelphia: W.B. Saunders Company, 1996.
3. Bennett JM, Catovsky D, Daniel MT, Flandrin G, Galton DAG, Gralnick HR, Sultan C: Proposals for the classification of the myelodysplastic syndromes. Br J Haematol 51:189–199, 1982.

4. Bennett JC, Plum F: ''Cecil Textbook of Medicine,'' 20th ed., Vol. 1. Philadelphia: W.B. Saunders Company, 1996.
5. Beutler E, Lichtman MA, Coller BS, Kipps TJ: ''Williams Hematology,'' 5th ed. New York: McGraw-Hill, Inc. 1995.
6. Dacie Sir JV, Lewis SM: ''Practical Hematology,'' 8th ed. Edinburgh: Churchill Livingstone, 1995.
7. Greenberg P, Cox C, LeBeau MM, Fenaux P, Morel P, Sanz G, Sanz M, Vallespi T, Hamblin T, Oscier D, Ohyashiki K, Toyama K, Aul C, Mufti G, Bennett J: International scoring system for evaluating prognosis in myelodysplastic syndromes. Blood 89:2079–2088, 1997.
8. Handin RI, Lux SE, Stossel TP: ''Blood: Principles and Practice of Hematology.'' Philadelphia: J.B. Lippincott Company, 1995.
9. Hardisty RM, Weatherall DJ: ''Blood and Its Disorders.'' Oxford: Blackwell Scientific Publications, 1974.
10. Hoffbrand AV, Pettit JE: ''Clinical Hematology: Basic Principles and Practice.'' Basle: Gower Medical Publishing, 1988.
11. Hoffman R, Benz EJ Jr, Shattil SJ, Furie B, Cohen HJ, Silberstein LE (eds): ''Hematology: Basic Principles and Practice,'' 2nd ed. New York: Churchill Livingstone, 1995.
12. Isselbacher KJ, Braunwald E, Wilson JD, Martin JB, Fauci AS, Kasper DL: ''Harrison's Principles of Medicine,'' 13th ed., Vol. 2. New York: McGraw-Hill, Inc., 1994.
13. Jandl JH: ''Blood: Textbook of Hematology,'' 2nd ed. Boston: Little, Brown and Company, 1996.
14. Lee GR, Bithell TC, Foerster J, Athens JW, Lukens JN: ''Wintrobe's Clinical Hematology,'' 9th ed., Vol. 1. Philadelphia: Lea & Febiger, 1993.
15. Miller DR, Baehner RL, McMillan CW: ''Blood Diseases of Infancy and Childhood,'' 5th ed. St. Louis: The C.V. Mosby Company, 1984.
16. Nathan DG, Oski FA: ''Hematology of Infancy and Childhood,'' 4th ed., Vol. 1. Philadelphia: W.B. Saunders Company, 1993.
17. Tierney LM, McPhee SJ, Papadakis MA: ''Current Medical Diagnosis and Treatment,'' 33rd ed. Appleton & Lange, 1994.
18. Weatherall DJ, Ledingham JGG, Warrell DA: ''Oxford Textbook of Medicine,'' 3rd ed., Vol. 3. Oxford: Oxford University Press, 1996.
19. Bottomley SS: Sideroblastic anemias. In Lee GR, Bithell TC, Foerster J, Athens JW, Lukens JN (eds): ''Wintrobe's Clinical Hematology,'' 9th ed., Vol. 1. Philadelphia: Lea & Febiger, 1993, p 852.
20. Nusbaum NJ: Genetic bases for sideroblastic anemia. Am J Hematol 37:41–44, 1991.
21. Bottomley SS, May BK, Cox TC, Cotter PD, Bishop DF: Molecular defects of erythroid 5-aminolevulinate synthase in X-linked sideroblastic anemia. J Bioenerget Biomembr 27:161–168, 1995.
22. Noble JS, Taylor GR, Losowsky MS, Hall R, Turner G, Mueller RF, Stewart AD: Linkage analysis of a large pedigree with hereditary sideroblastic anaemia. J Med Genet 32:389–392, 1995.
23. Cox TC, Kozman HM, Raskind WH, May BK, Mulley JC: Identification of a highly polymorphic marker within intron 7 of the ALAS2 gene and suggestion of at least two loci for X-linked sideroblastic anemia. Hum Mol Genet 1:639–641, 1993.
24. Raskind WH, Wijsman E, Pagon RA, Cox TJ, Bawden MJ, May BK, Bird TD: X-linked sideroblastic anemia and ataxia: Linkage to phosphoglycerate kinase at Xq13. Am J Hum Genet 48:335–341, 1991.
25. Prasad AS, Tranchida L, Konno ET, Berman L, Albert S, Sing CF, Brewer GJ: Hereditary sideroblastic anemia and glucose-6-phosphate dehydrogenase deficiency in a negro family. J Clin Invest 47:1415–1424, 1968.
26. Pagon RA, Bird TD, Detter JC, Pierce I: Hereditary sideroblastic anaemia and ataxia: An X-linked recessive disorder. J Med Genet 22:267–273, 1985.
27. Kasturi J, Basha HM, Smeda SH, Swehli M: Hereditary sideroblastic anemia in 4 siblings of a Libyan family: Autosomal inheritance. Acta Haematol 68:321–324, 1982.
28. van Waveren Hogervorst GD, van Roermund HPC, Snijders PJ: Hereditary sideroblastic anemia and autosomal inheritance of erythrocyte dimorphism in a Dutch family. Eur J Haematol 38:405–409, 1987.
29. Jardine PE, Cotter PD, Johnson SA, Fitzsimons EJ, Tyfield L, Lunt PW, Bishop DF: Pyridoxine-refractory congenital sideroblastic anaemia with evidence for autosomal inheritance: Exclusion of linkage to ALAS2 at Xp11.21 by polymorphism analysis. J Med Genet 31:213–218, 1994.
30. Barrett TG: Thiamine-responsive anaemia, deafness and diabetes. Br J Haematol 89(Suppl 1):9, 1995.
31. Poggi V, Longo G, DeVizia B, Andria G, Rindi G, Patrini C, Cassandro E: Thiamin-responsive megaloblastic anaemia: A disorder of thiamin transport? J Inherited Metab Dis 7:153–154, 1984.
32. Rawles JM, Weller RO: Familial association of metabolic myopathy, lactic acidosis and sideroblastic anemia. Am J Med 56:891–897, 1974.
33. Shoffner JM: Maternal inheritance and the evaluation of oxidative phosphorylation diseases. Lancet 348:1283–1288, 1996.
34. Johns DR: Mitochondrial DNA and disease. N Engl J Med 333:638–644, 1995.
35. Casademont J, Barrientos A, Cardellach F, Rotig A, Grau J-M, Montoya J, Beltran S, Cervantes F, Rozman C, Estivill X, Urbano-Marquez A, Munos V: Multiple deletions of mt DNA in two brothers with sideroblastic anemia and mitochondrial myopathy and in their asymptomatic mother. Hum Mol Genet 3:1945–1949, 1994.
36. Pearson HA, Lobel JS, Kocoshis SA, Naiman JL, Windmiller J, Lammi AT, Hoffman R, Marsh JC: A new syndrome of refractory sideroblastic anemia with vacuolization of marrow precursors and exocrine pancreas dysfunction. J Pediatr 95:6,976–984, 1979.
37. McShane MA, Hammans SR, Sweeney M, Holt IJ, Beattie TJ, Brett EM, Harding AE: Pearson syndrome and mitochondrial encephalomyopathy in a patient with a deletion of mtDNA. Am J Hum Genet 48:39–42, 1991.
38. Smith OP, Hann IM, Woodward CE, Brockington M: Pearson's marrow/pancreas syndrome: Haematological features associated with deletion and duplication of mitochondrial DNA. Br J Haematol 90:469–472, 1995.
39. Bernes SM, Bacino C, Prezant TR, Pearson MA, Wood TS, Fournier P, Fischel-Ghodsian N: Identical mitochondrial DNA deletion in mother with progressive external ophtalmoplegia and son with Pearson marrow-pancreas syndrome. J Pediatr 123:598–602, 1993.
40. Larsson NG, Holme E, Kristiansson B, Oldfors A, Tulinius M: Progressive increase of the mutated mitochondrial DNA fraction in Kearns-Sayre syndrome. Pediatr Res 28:131–136, 1990.
41. Nakase H, Moraes CT, Rizzuto R, Lombes A, DiMauro S, Schon EA: Transcription and translation of deleted mitochondrial genomes in Kearns-Sayre syndrome: Implications for pathogenesis. Am J Hum Genet 46:418–427, 1990.
42. Nelson I, Bonne G, Degoul F, Marsac C, Ponsot G, Lestienne P: Kearns-Sayre syndrome with sideroblastic anemia: Molecular investigations. Neuropediatrics 23:199–205, 1992.
43. Borgna-Pignatti C, Marradi P, Pinelli L, Monetti N, Patrini C: Thiamine-responsive anemia in DIDMOAD syndrome. J Pediatr 114:405–410, 1989.
44. Rötig A, Cormier V, Chatelain P, Francois R, Saudubray JM, Rustin P, Munnich A: Deletion of mitochondrial DNA in a case of early-onset diabetes mellitus, optic atrophy and deafness (DIDMOAD, Wolfram syndrome). J Inherited Metab Dis 16:527–530, 1993.
45. Bader-Meunier B, Rötig A, Mielot F, Lavergne JM, Croisille L, Rustin P, Landrieu P, Dommergues JP, Munnich A, Tchernia G: Refractory anaemia and mitochondrial cytopathy in childhood. Br J Haematol 87:381–385, 1994.
46. Gattermann N, Retzlaff S, Wang Y-L, Berneburg M, Heinisch J, Wlaschek M, Aul C, Schneider W: A heteroplasmic point mutation of mitochondrial $tRNA^{leu(CUN)}$. In non-lymphoid haemopoietic cell lineages from a patient with acquired idiopathic sideroblastic anaemia. Br J Haematol 93:845–855, 1996.
47. Inbal A, Avissar N, Shaklai M, Kuritzky A, Schejter A, Ben-David E, Shanske S, Garty B-Z: Myopathy, lactic acidosis, and sideroblastic anemia: A new syndrome. Am J Med Genet 55:372–378, 1995.

48. Gattermann N, Aul C, Schneider W: Two types of acquired idiopathic sideroblastic anaemia (AISA). Br J Haematol 74:45–72, 1990.
49. Garand R, Gardais J, Bizet M, Bremond J-L, Accard F, Callat M-P, de Bouchony ET, Goasguen J-E: Heterogeneity of acquired idiopathic sideroblastic anaemia (AISA). Leuk Res 16:463–468, 1992.
50. Cotter PD, May A, Fitzsimons EJ, Houston T, Woodcock BE, Al-Sabah AI, Wong L, Bishop DF: Late-onset X-linked sideroblastic anemia. J Clin Invest 96:2090–2096, 1995.
51. Sessarego M, Scarra GB, Giuntiti P, Ajmar F: On the Xq13 breakpoint: Clinical and cytogenetic observations in a patient with acute myelogenous leukemia. Acta Haematol 70:134–136, 1983.
52. Dewald GW, Brecher M, Travis LB, Stupca PJ: Twenty-six patients with hematologic disorders and X chromosome abnormalities. Frequent idic(X)(q13). chromosomes and Xq13 anomalies associated with pathologic ringed sideroblasts. Cancer Genet Cytogenet 42:173–185, 1989.
53. Dierlamm J, Michaux L, Criel A, Wlodarska I, Zeller W, Louwagie A, Michaux J-L, Mecucci C, van den Berghe H: Isodicentric (X)(q13) in haematological malignancies: Presentation of five new cases, application of flourescence in situ hybridization (FISH) and review of the literature. Br J Haematol 91:885–891, 1995.
54. Mecucci C, van Orshoven A, Vermaelen K, Michaux JL, Tricot G, Louwagie A, Delannoy A, van den Berghe H: 11 q-chromosome is associated with abnormal stores in myelodysplastic syndromes. Cancer Genet Cytogenet 27:39–44, 1987.
55. Nicholls MD, Atkinson K, Biggs JC, Concannon AJ, Dodds AJ: Late onset pyridoxine-responsive sideroblastic anaemia after allogeneic bone marrow transplantation. Br J Haematol 56:153–156, 1984.
56. O'Brien H, Amess JAL, Mollin DL: Recurrent thrombocytopenia, erythroid hypoplasia and sideroblastic anaemia associated with hypothermia. Br J Haematol 51:451–456, 1982.
57. Brodsky RA, Hasegawa S, Fibach E, Dunbar CE, Young NS, Rodgers GP: Acquired sideroblastic anaemia following progesterone therapy. Br J Haematol 87:859–862, 1994.
58. Fiske DN, McCoy HE III, Kitchens CS: Zinc-induced sideroblastic anemia: Report of a case, review of the literture, and description of the hematologic syndrome. Am J Hematol 46:147–150, 1994.